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MEMORANDUM REPORT 70-7

AN INVESTIGATION OF THE EFFECTS OF A HELIUM-OXYGEN BREATHING MIXTURE ON HEARING IN NAVAL PERSONNEL

by

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Bureau of Medicine and Surgery, Navy Department
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Naval Submarine Medical Center

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NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY
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SUMMARY PAGE

THE PROBLEM

To determine whether or not breathing a helium-oxygen mixture at one atmosphere affects hearing sensitivity.

FINDINGS

No marked effect on hearing was observed due to breathing a helium-oxygen mixture at surface pressures for a period of thirty minutes.

APPLICATION

These findings provide a basis for interpreting the results of experiments in underwater hearing with divers breathing helium-oxygen mixtures.

ADMINISTRATIVE INFORMATION

This investigation was conducted under Bureau of Medicine and Surgery Research Work Unit MF12.524.004-9012D -- Effects of Submarine Environments and Operations on Hearing. The present report is number 7 on that work unit. The manuscript was approved for publication on 18 September 1970 and designated as Submarine Medical Research Laboratory Memorandum Report No. 70-7.

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ABSTRACT

Hearing levels of three subjects were measured at 125, 1000 and 8000 Hertz while the subjects were breathing air and while breathing an 80%/20% mixture of helium and oxygen. No significant change in hearing levels which could be attributed to the effects of the gas breathed were detected during or following a thirty-minute period on helium-oxygen.

THE EFFECTS OF A HELIUM-OXYGEN MIXTURE ON HEARING OF NAVAL PERSONNEL

INTRODUCTION

Experiments on underwater hearing in man have been reported,[1,2] in which attempts were made to determine the relative importance of the ear canal-middle ear and bone conductive pathways to underwater hearing. The evidence indicates either that the ear canal-middle ear route is not functional underwater, or that, as Sivivan[3] and Ide[4] suggested, the ear canal-middle ear pathway and the bone conduction pathways are nearly equally efficient in transmitting energy from the water to the cochlea. The available data do not provide a basis for deciding between these two alternatives.

In order to obtain further evidence, it is desirable to alter the characteristics of the possible conductive paths and to observe the effects of such alterations on underwater hearing sensitivity. It may be possible to alter the functioning of the middle ear apparatus by introducing helium-oxygen (HeO_2) into the cavity. Since an 80%/20% mixture of HeO_2 has an acoustic impedance some three times that of air, it seems possible that the compliance of the middle ear cavity would change sufficiently to result in a change in hearing sensitivity. In order to test this possibility, the experiment described below was conducted in air at surface pressure.

METHOD

Subjects: Three graduate assistants, two males and one female, served as subjects. All three were in their early or mid-twenties and had no marked hearing impairments. All had some experience as observers in psychoacoustic studies.

Apparatus: The subjects were tested in a soundproof room. Pure tones of 125, 1000, and 8000 Hertz were generated by a Hewlett-Packard 200 ABR oscillator, gated on and off by a Grason-Stadler 829E electronic switch with a rise-fall time of 10 milliseconds, an on-off ratio of 1.00 and a 250 millisecond pulse length. This signal was passed through a Grason-Stadler Model E 3262A recording attenuator and an impedance matching transformer to a telephonix TDH-39 earphone. The HeO_2 was obtained from a 300 cubic foot bottle and administered through a diver's full face mask equipped with a two-stage demand regulator.

Procedure: Auditory thresholds were measured at each of the three frequencies. The diving mask was then donned and HeO_2 was administered. Auditory thresholds were again measured. The subject then continued breathing the HeO_2 mixture for a period of thirty minutes, at the end of which time auditory thresholds were again measured. Finally, the face mask was removed and thresholds measured for a fourth time. Subjects were instructed to ventilate the middle ear cavity upon changing from breathing air to HeO_2, and again upon changing back to breathing air. Thus, it was hoped that three distinct effects could be measured: (1) a measure of the effects of HeO_2 in the middle ear with little or no systemic HeO_2 present (first threshold under

HeO_2); (2) a measure of the effects of HeO_2 in the middle ear with systemic HeO_2 present, (second threshold under HeO_2); and (3) a measure of the effects of air in the middle ear with systemic HeO_2 present, (second threshold under air).

RESULTS AND DISCUSSION

The results of the various threshold measurements are shown in Table I. With tbe small sample used, a change in threshold must be about 5 db in order to be significant. From a practical standpoint, any effect ougbt to be from 5 to 10 db to be reliably detected in underwater experiments with moderate sized samples, because of the rather poor reliability of underwater threshold measurements [1].

Table I indicates that no significant changes occurred in auditory sensitivity at 125 or 1000 Hertz as a result of breathing the HeO_2 mixture. A minus-8 db change occurred at 8000 Hz, a fact which appears to be significant, since all three subjects exhibited a depression of sensitivity which ranged from -5 to -11 db immediately after switching to HeO_2. However, with continued respiration of HeO_2, tbe effect tended to disappear.

If HeO_2 in tbe tympanic cavity were responsible for the initial shift at 8000 Hz, it would appear that some adaptive process tended to restore bearing to normal levels, or tbat systemic HeO_2 tended to produce an improvement in high frequency sensitivity whicb counteracted the decrement produced by tympanic HeO_2. Concerning the first possibility, it is known that gas is exchanged between the surrounding tissue and the middle ear cavity [5]. During the thirty-minute period of HeO_2 respiration, the build-up of tbe gas in the tissues would not be so great that tissues would be saturated, nor would all nitrogen (N) be eliminated [6]. Conceivably then, middle ear He could have been partially replaced by N through gas excbange between the cavity and surrounding tissues. Subjects were instructed to ventilate the

Table I. Mean changes in auditory thresholds at three frequencies due to respiration of 80% Helium-20% Oxygen breathing mixture. Values are in decibels relative to hearing levels prior to administration of HeO_2. Negative values indicate depressed sensitivity.

Frequency (Hz)	1st HeO_2	2nd HeO_2	3rd HeO_2
125	1.6	.6	3.3
1000	- .7	-1.7	- .7
8000	-8.0	-3.0	-1.7

middle ear cavity only after changing from air to HeO_2, and from HeO_2 to air. Spontaneous ventilation occurs at such a slow rate (1-2 ml per 24 hours)[5] that a compensatory amount of HeO_2 may not have been delivered to the middle ear via the Eustachian tube during the HeO_2 breathing period. Thus, the middle ear would contain less and less He and more and more N as the experiment continued.

Concerning the second possibility, that HeO_2 has a facilatory effect on high frequency hearing, there appears to be no evidence to support such a view. Had such an effect occurred, it would have been revealed by the post-HeO_2 threshold measurement.

Brandt[8] measured underwater hearing levels at 125 through 8000 Hertz, using divers breathing HeO_2 at 105 feet, and found thresholds to be significantly higher by about five db than thresholds measured at the same depth with divers breathing compressed air. This effect was attributed to the presence of HeO_2 in the middle-ear cavity. Such a finding is not incompatible with the present data. It is conceivable that an interactive effect between respired gas and pressure occurs such that little or no change occurs at surface pressures, but a significant amount does occur at greater pressures. Such is the case with gas narcosis[7]. However, rather than assume such an interaction, it would be well to study such effects directly in a dry chamber. Later, Hollien and Brandt stated that no differences in thresholds were found in a comparison of hearing between air-filled and HcO_2-filled middle ears[9]. They felt that this indicated that the middle ear mechanism is not functional underwater since the presence of HeO_2 in the middle ear would alter the impedance of the middle ear cavity. This impedance change was presumed to produce a change in sensitivity. The present data show this not to be the case.

CONCLUSION

It may be concluded that respired HeO_2 at surface pressures has little or no effect on hearing sensitivity at 125 and 1000 Hz. A small decrement in auditory thresholds may occur at higher frequencies. However, the effect, if any, is not of sufficient magnitude or generality to be of practical importance. This does not preclude the possibility that effects may be found at pressures greater than one atmosphere.

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